

A General Framework for Dynamic Decision Analysis in Medicine

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Dynamic decision analysis concerns problems in which time and uncertainty are explicitly considered. Existing dynamic decision modeling techniques in medicine include Markov cycle trees [1], stochastic trees [2], and dynamic influence diagrams [3].

One major difficulty in formulating dynamic decision models in existing frameworks is to fit the complex decision factors into simple, parameterized models; many assumptions and constraints are implicit in the models. The limited decision vocabulary contributes toward solution efficiency, but obscures model transparency.

We introduce a prototype dynamic decision modeling system that supports multiple perspective reasoning and incremental vocabulary extension. To address the trade-off between solution efficiency and model transparency, DYNAMO (for DYNAMIC decision MODELing system) supports flexible, explicit, and concise specification and visualization of decision parameters, and admits various solution methods. A user can focus on the different phases of dynamic decision modeling separately; the system will organize the relevant information for easy access and analysis. This framework integrates approaches in decision theory, control theory, and artificial intelligence.

Model formulation in DYNAMO is in terms of an extensible vocabulary for decision factors and constraints. Examples of decision factors include alternate actions and strategies, possible state transitions, chance events that may occur between state transitions, and relevant probability distributions with respect to time. Examples of decision constraints include applicability conditions of the actions, validity conditions of the states, and logical statements among the states and/or events. Unlike current techniques, the decision parameters can be visualized in multiple per-

spectives. Multiple text and graphical interfaces facilitate input and output of the decision parameters in different but consistent ways. For instance, we can characterize state transitions directly as probability distributions, or in terms of intermediate chance events. Precise correspondence is established among the different perspectives. At different stages of model formulation, such multiple perspective reasoning helps to explicate the model at different levels of details.

The mathematical representation of a model in DYNAMO is a semi-Markov decision process; it supports efficient solution and formal analysis. Different solution methods are admissible depending on the model assumptions. Unlike current techniques, these solution methods are not restricted by the graphical structure of the model. The model solution is an optimal policy, i.e., it provides decision guidelines and insights to all possible variations of the decision context. Besides the formal basis, sensitivity analysis is facilitated by the modular and explicitly organized model information and solution formats.

We have demonstrated, in a comprehensive case study in atrial fibrillation management, that DYNAMO is capable of handling actual dynamic decision problems in medicine. We are interested in putting the system into practical clinical use. Towards this end, we have also examined how the system and its underlying methodology can be incrementally extended.

References

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